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OVERSIZED ISO-FREIGHT CONTAINER: DESIGNED TO BE USED AS AN IP-2 TRANSPORT PACKAGE

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ABSTRACT

Sellafield Ltd. currently requires a new oversized ISO freight container that can fully contain other standard sized 20ft ISO freight containers and stillages for transport as an IP-2 Transport Package. There is an existing historic ISO freight container which is coming to the end of its operational life and the new higher performing oversized ISO freight container is needed to meet continued future transports.

The new asset will enable various waste items to be loaded in standard 20ft ISO freight containers and stillages that do not comply themselves with IP-2 Transport Package requirements to be transported off-site to an appropriate disposal facility. The availability of the new oversized ISO freight container will provide Sellafield Ltd with a valuable transport alternative. The ISO freight container is to be licensed as a Type IP-2 in accordance with the IAEA SSR-6 Regulations for the Safe Transport of Radioactive Material (Ref. 1). This paper provides an overview of the design for manufacture and the compliance requirements to meet relevant ISO standards and the additional requirements imposed for Type IP-2 Transport Packages.

In summary the oversized ISO freight container will be side opening, with an internal stainless steel liner. The side opening door will operate with use of hydraulic actuators powered from an on-board power pack and by the use of limit switches for control. The door will have an elastomeric seal with an interspace that can be pressurized for testing. The door is fixed to the container for transport through fixings that are manually engaged.

The internal stainless steel liner will be welded to the container body and door, and fully sealed to allow the cavities between the liner and the container body/door to be pressurised. The cavity tests in combination with the elastomeric door seal interspace test will prove the packages containment. This ability to test containments is necessary for the IP-2 Transport Package requirements. The ISO freight container will be fixed to a standard trailer with standard 1CC ISO fittings. However, the design is larger than a 1C floor plan and so the bottom corner fittings will not be in the corners of the container.

BACKGROUND

Now, as a wholly owned subsidiary of the Nuclear Decommissioning Authority (NDA) Sellafield Ltd. is currently transitioning from a predominantly reprocessing and storage site into a clean-up and decommissioning site. To enable this wide scale decommissioning, Sellafield Ltd. is actively exploring alternatives that will ensure versatility for emerging decommissioning options. One such enabler already on the Sellafield site and owned by the Waste Monitoring and Compaction Plant (WAMAC) is an oversized ISO container which is licensed as an IP-2 transport package in accordance with the IAEA Transport Regulations (Ref. 1).

The package has been operating on the Sellafield site for the past 25 years and due to its adaptability, has played a key role in hazard reduction.

The package is primarily designed for the transport of Low Specific Activity and Surface Contaminated Objects classified as Low Level waste (LLW), under ‘exclusive use’, between the Low Level Waste Repository at Drigg and the Sellafield WAMAC facility. The scope of use of the package has been expanded to transporting suitably restrained metal items and damaged containers between other licensed sites in the NDA estate.

This asset will inevitably be retired within the near future; this coincides with Sellafield Ltd.’s acceleration in decommissioning. Therefore, to augment and eventually replace the existing oversized ISO container, a new container is needed.

INTRODUCTION

The existing oversized ISO container (Figure 1, 2, 3) can fully contain other standard sized 20 ft ISO containers and stillages containing radioactive material to be transported on the UK roads. The use of this package has provided Sellafield Ltd. with a valuable transport alternative.

The container is side opening with an internal stainless steel liner that can fully encompass and seal a 1CC container or a stillage. To be able to support current and future decommissioning activities an additional Type IP-2 oversized container is needed.

The new oversized ISO container is required to meet the main design features of the existing oversized container. However, it is also required to be designed for enhanced performance and improved operational safety.

Figure 1 Existing oversized ISO container Type IP-2 transport package with the door open and 1CC

OVERSIZED ISO FREIGHT CONTAINER DESIGN

Existing design

The existing container is designed to conform ISO 1496-1 (Ref. 2), excluding ratings and dimensions. It is designed such that if subjected to the tests prescribed in the standard and to the accelerations occurring during routine conditions of transport it would prevent loss or dispersal of the radioactive contents.

The existing design entered service in 1995 is a 7238mm x 2881mm x 3490mm high freight container. It is constructed of a corrugated carbon steel outer structure over a stainless steel liner to provide a good de-contaminable surface. The inner face of the door is also lined in stainless steel. The container features a hydraulically actuated side opening door which is secured in place using 34 swing bolts, a double-seal arrangement with an incorporated interspace test point, as well as a high efficiency particulate filter to prevent container pressurisation. The bolts are used to compress the seal and require operators working at height to manually apply the required torque. There are top and bottom ISO corner fittings and forklift pockets to facilitate lifting.

Figure 2 Door operations using Hydraulic Arms

Design improvements for the new oversized ISO container

The need to procure a new oversized ISO container (Figure 4) presented the opportunity to improve on the existing features of the current asset. Key design requirements for the new oversized container are as follows:

- Increased payload: the new container is designed to maximise payload mass as far as is reasonably practicable within 42te gross weight limit
- Increased size: the dimensions of the new container are 8450mm x 2887mm x 3910mm high (the width limit is 3000mm)
- Operational life: minimum of 260 operational cycles per year, for 20 years, with a minimum road haulage distance of 48,000 miles per year
- Door operations must not include working at height to reduce operator risks
- Remote door operations: for opening, closing and seal compression to reduce operator risks
- Manual mechanical means to secure the door to ensure required seal compression for transport
- Payload restraint to avoid load tipping
- Improved door seal performance

Figure 3 Door in 'parked' position, allowing full access to transport package

DESIGN CHALLENGES

Door seal compression

The requirement to remove the need to work at height (and therefore the removal of the 34 swing bolts) presented a design challenge: how to compress the double elastomeric door seal evenly over the 7m door length and secure it in its required position for transport?

An optioneering study was undertaken to determine most suitable designs to compress the door seal; one option was the use of hydraulic 'swing cylinders'.

Swing cylinders are hydraulically operated self-locking clamps which are generally used to restrain work-pieces in machinery. However, the clamping force generated by each swing cylinder in combination with its 90° rotating tool head and self-locking mechanism (not requiring active hydraulic power to remain locked) proved to be the highest scoring option. Unfortunately, after further research it was discovered that the swing cylinders considered had not been fully certified for use in costal environment. The overall cost, complexity and time for testing made it unfeasible to continue. The other design option was to use hydraulic actuators for both the seal compression and the door opening & closing cycles. The seal compression will be maintained during transport when the hydraulic system is inactive, through the application of manual container locking bars.

Figure 4 Concept oversized IP-2 container design CAD model showing the door and proposed hydraulic actuators

A finite element analysis was performed on the container door, to assess the overall structural performance of the door under load, during hydraulic actuation, from the door seal.

Figure 5 shows the door model and highlights the biggest impact to seal compression resulted from the reduction in seal stiffness from 300kN to100kN, and the inclusion of additional hydraulic rams at the top and bottom mid-plane of the container door (Figure 6).

The analysis considers the interaction between the door seal and the door deformation over the 7m length of the oversized container door.

A manual mechanical means of securing the door in its required position, to ensure seal compression, is needed for transport; the hydraulic system cannot be powered during transportation. The door is secured by 8 standard locking bars evenly located across the container door length (Figure 7).

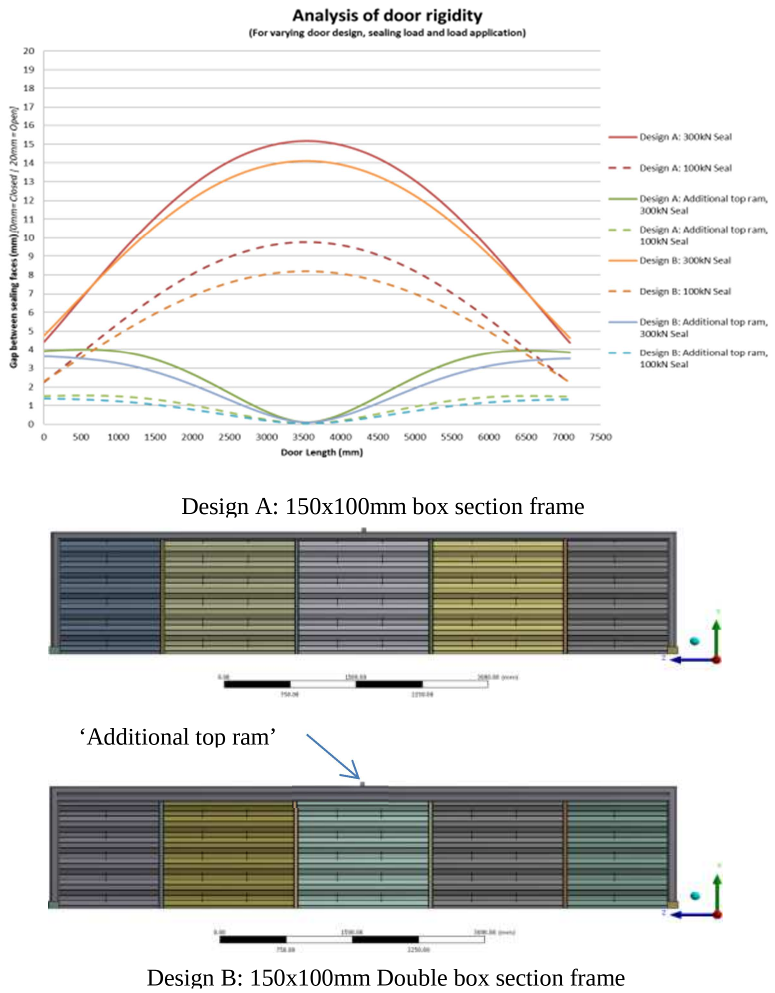

Figure 5 [Top] Comparison of seal compression over the door length. [Bottom] a sample of the door models analysed.

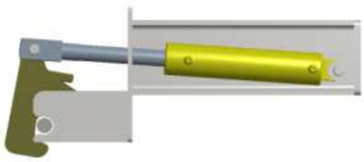

Figure 6 Additional hydraulic door clamping mechanism

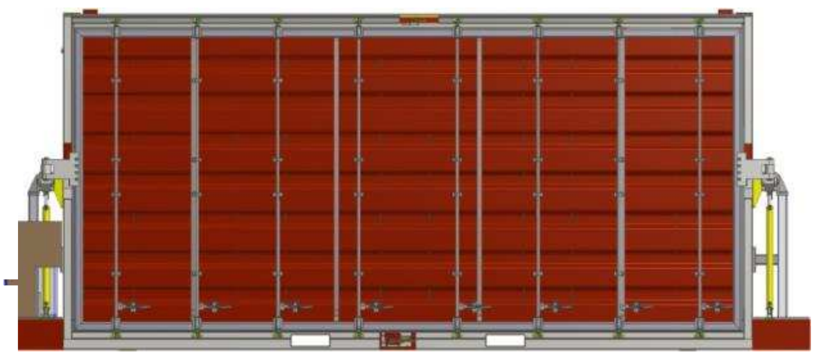

Figure 7 Container locking bars used to constrain the door and maintain seal compression during transport

The container door seal is being developed to suit the design of the door. Figure 8 shows the compression tests of two sections of the proposed door seal (utilising an existing door seal design), a constrained section, and unconstrained section of the existing seal. The compression tests concluded that the door seal required a compression load of 300kN to compress the required 20mm. This compression load was too high, and therefore a new design was needed.

The specification for the new seal is a 60mm thick double chamber design which must not take more than 100kN to compress a minimum of 20mm. The 100kN comes from the door sealing reaction forces in the most deflected area with a stiffened door: the central span. The seal is required to undergo appropriate testing to ensure that it can perform nominally in temperatures ranging from -10 °C to +38 °C, be able to withstand a minimum of 2600 cycles and have an operational life of at least 10 years in a costal environment without undue compression set. The seal material for construction is either Ethylene Propylene Diene Methylene (EPDM) or Fluorocarbon rubber (FKM/FPM), and the decision will be based on the seal performance under test conditions. The seal interspace test will confirm the adequacy of the design by not exceed the leakage rate of 0.1 Pa m3 s-1 SLR, when compressed by a maximum of 5mm. This pass criteria, although challenging, is to provide further confidence for the containment leakage tests before, during and after the required ISO 1496-1 (Ref. 2) tests.

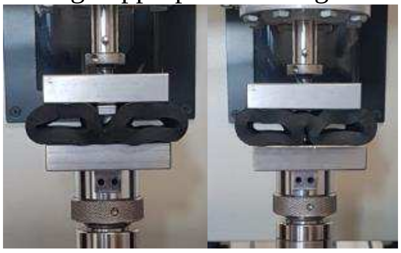

Figure 8 Seal compression test [L] constrained seal section [R] 'Free' seal section

DOOR CLOSURE SYSTEM & DOOR LOCKING

Door 'crabbing'

The existing design for the container door operations has a noticeable 'door crabbing' action during hydraulic actuation; probably due to the variation in speed between the hydraulic actuators. This tends to place uneven loading on door brackets leading to unwanted high stresses.

Figure 9 CAD concepts for the door closure system: [L] Hydraulic actuation and supporting frame [[R] Additional hydraulic door clamping mechanism

To mitigate eccentric loading forces on the door brackets during this potential 'crabbing' movement the door bracket design is strengthened but with additional flexibility in movement. The door hinges are individual machined features, removing stress concentrations and weak points during potential uneven hydraulic actuation.

The hydraulic support mechanisms shown in Figure 9 are located to the sides of the container, supported by an A-Frame, with three distinct mounting points. The design is optimised for door a normal operation (door weight approx.2te) which includes wind loading and eccentric door movement scenarios.

PACKAGE OVERALL SIZE AND WEIGHT CONSTRAINTS

Increased payload

The oversized container is to be designed to maximise the payload mass as far as reasonably practicable up to the 42te gross weight limit. This will allow the existing on site forklift truck to be used to handle the package.

Experience has shown that loading standard general purpose full height 20ft ISO containers to under 23te has been challenging. Flexibility is therefore required to increase the maximum loaded weight of the standard general purpose full height 20ft ISO container. This will also avoid re-packing overloaded containers and the potential for radiation dose exposure to workers. The desired weight limit is around 28te for a loaded standard general purpose full height 20ft ISO container. Also, the oversized ISO container dimensions are increased to allow for greater flexibility during loading and unloading of larger items.

The oversized ISO container design must be capable of passing the ISO 1496-1 (Ref.3) tests whilst maintaining containment of the internal payload cavity. The increase in payload for the oversized ISO container (approx.5te) has required an increase in the structural strength to meet the ISO 1496-1(Ref.3) tests. The structure has been strengthened by the use of additional section members; welded using full penetration welds. The material used is carbon steel S355 with yield strength of 355 MPa.

To gain confidence in the design all relevant ISO 1496-1 (Ref.3) test loadings are applied, using finite element analysis, to assess the structural integrity and satisfy package containment requirements.

ISO 1496-1 tests assessed in the FEA (30te payload used for additional pessimism) are as follows;

- Test 1 Stacking - apply load on all four top corners simultaneously and 1.8 times the gross mass minus the tare weight applied to the internal floor
- Test 2 Lifting from top corner fittings - This test lifts the container from the top four ISO corners with 2 times the gross mass minus the tare weight evenly distributed in the container
- Test 3 Lifting from bottom corner fittings (45^{e}) - This test lifts the container from the bottom four ISO corner fitting at 45 degrees to the horizontal with 2 times the gross mass minus the tare weight evenly distributed in the container.
- Test 4 Restraint (Longitudinal) -This test holds one side of the bottom ISO corner fittings and pulls and pushes the other side horizontally with a force of 2 times the gross mass. This is conducted with the maximum payload evenly distributed inside the container.
- Test 5 Strength of End Walls- This test evenly applies a force of 40% the payload times gravity to the end wall of the container
- Test 6 Strength of Side Walls - This test evenly applies a force of 60% the payload times gravity to the side wall of the container
- Test 7 Strength of Roof - This test applies a mass of 300kg uniformly distributed over an area of 600x300mm at the weakest area of the roof.
- Test 8 Floor Strength - This test applies 3630kg in two areas 185x100mm in size that are 760mm apart. The load is moved around the whole container floor.
- Test 9 Rigidity (transverse) - This test applies a force of 150kN to two top ISO corner fittings in the lateral direction first towards the container then way from it. It is restrained on the bottom ISO corner fittings in the vertical direction, lateral restraint is only provided at the bottom ISO corner fitting diagonally opposite to and in the same end frame as the top ISO corner fitting to which the force is applied.
- Test 10 Rigidity (longitudinal) - This test applies 75kN to the two top ISO corner fittings on one end. It is restrained vertically by all bottom ISO corner fittings and longitudinally constrained by the fitting diagonally opposite to and in the same side frame as the top ISO corner fitting to which the force is applied.
- Test 11 Lifting from Fork Lift Pockets - This test lifts the container with the supplied fork lift pockets with 1.6 times the payload evenly distributed inside the container

Acceptance criteria **-** Stresses within the container can be assessed to a design standard. However, ISO containers are generally expected to exceed yield stress in small areas during these tests as it will not affect the integrity of the container. Therefore, assessing the container to these standards is considered too onerous for the intended use. The structure is assessed to the yield stress of the material, and will only be considered failing if there are significant areas of yielding. There is also specific acceptance criteria defined in BS ISO 1496-1 (Ref.3), such as the following:

"5.3.4 For all containers under dynamic conditions, or the static equivalent thereof, with the container having a load uniformly distributed over the floor in such a way that the combined mass of the container and test load is equal to 1,8 R, no part of the base of the container shall deflect more than 6 mm below the base plane (bottom faces of the lower corner fittings)."

"5.4 The sideways deflection of the top of the container with respect to the bottom of the container, at the time it is under full transverse rigidity test conditions, shall not cause the sum of the changes in length of the two diagonals to exceed 60 mm."

"5.5 The longitudinal deflection of the top of the container with respect to the bottom of the container, at the time it is under full longitudinal rigidity test conditions, shall not exceed 25 mm."

Way forward **-** The finite element analysis shows that the oversized ISO container will successfully pass majority of the tests required. There are however, several issues for considerations:

- The container must not be tested for stacking. This should not be an issue as long as the container is appropriately labelled as a non-stackable container in accordance with BS EN ISO 6346 (Ref. 3).
- Sharp corners in areas such as the corner braces and fork lift pockets need to be removed as best as possible.
- The sealing face on the body may move by up to 20mm vertically downward in relation to the door. This must be taken into account for the seal design in order to maintain a seal during these tests.
- Stiffening plates to be added to the bottom ISO corner fittings on the non-door side of the container. This is required to reduce the stress in the bottom flange to an acceptable level during the longitudinal restraint test (test 4).

PAYLOAD RESTRAINT

Payload 'tipping'

The payload needs to be securely stowed within the package. The securing arrangement should avoid movement in the longitudinal and transverse directions and the potential for load 'tipping' (note increased new container payload around 28te).

4 off UIC stainless steel cast spigots (Ref. 4 - UIC CODE 571-4 Standard Wagons - Appendix C) will be welded to the container floor main structure to provide the required restraint; at spacing suitable for a standard 20ft 1CC ISO container.

In order to substantiate the restraint system, calculation are performed for shear and bending loads for the securing welds under routine conditions of transport for the increased new container payload.

COMPLIANCE WITH REGULATIONS

Overview

Background on alternative methods presented in the IAEA Transport Regulations to qualify fright containers as Type IP-2 or Type IP-3, can be found in Ref.6. Changes in the regulations are summarised as follows;

- 1973 revised edition of the IAEA Transport Regulations (Ref. 6) first introduced freight containers for the transport of radioactive material- more as an 'overpack' to protect contents
- First issue of 1985 IAEA Transport Regulations (Ref. 7) brought in definitions for
    - LSA-I, LSA-II, LSA-III and SCO-I, SCO-II, SCO-III and
    - required packaging standards as Type-1, Type-2 and Type-3

  Also, included freight containers as Type-2 and Type-3 and allowed as an alternative qualification if designed and tested to ISO 1496-1 (Ref 3) plus the prevention of the 20% increase in radiation levels

- Amended issue of the 1985 IAEA Transport Regulations (as amended 1990) brought in requirement to 'prevent lose or dispersal of radioactive material' for the ISO 1496-1 (Ref 3) tests.
- Para 629 of the 2012 IAEA Transport Regulations (Ref. 1) covers the alternative requirements for freight containers to be used as Type-2 and Type-3 and allows the use of the ISO 1496-1 (Ref. 2) to prove acceptability.

IAEA Transport Regulations requirements

The new oversized ISO container will be licenced to the IAEA Transport Regulations (Ref. 1) as an IP-2 package for use on UK roads only.

The transportation of radioactive materials in the UK has to meet the Carriage of Dangerous Goods Regulations 2009 (as amended 2011) (Ref. 8). These regulations implement provisions of European legislation on the carriage of dangerous goods and, in particular for road transport apply the requirements contained in the European Agreement concerning the International Carriage of Dangerous Goods by Road generally referred to as 'ADR' (Ref. 9).

The international agreements, ADR (and other modal transports) are based upon the recommendations on the Transport of Dangerous Goods Model Regulations published by the United Nations, of which the requirements for the transport of radioactive material are based upon the IAEA Transport Regulations (Ref. 1). For simplicity reference is made to the IAEA Transport Regulations (Ref. 1) and the paragraph numbers therein.

The design must be compliant with the IAEA Transport Regulations (Ref.1) regarding alternative requirements for type IP-2 and Type IP-3; and in particular the requirements for *freight* containers.

Freight container *definition para 223…………of a permanent character and accordingly strong enough to be suitable for repeated use; specially designed to facilitate the transport of goods, by one or other modes of transport, without intermediate reloading, designed to be secured and/or readily handled, having fittings for these purposes*.

IAEA Transport Regulations (Ref.1) para 629 states that freight containers with the characteristics of a permanent enclosure may also be used as Type-2 or Type-3 provided that

- *The radioactive contents are restricted to solids.*
- *They satisfy the requirements for Type IP-1 specified in paragraph 623* – (paragraphs 607-618 define the general requirements for all packaging and packages, while paragraph 636 states the smallest external dimension of the package shall not be less than 10cm)
- *They are designed to conform to the International Organisation for Standardization document ISO 1496-1: series 1 freight Containers –specifications and testing- Part 1: General Cargo Containers for General purposes excluding dimensions and ratings. They shall be designed such that if subjected to the tests prescribed in that document and to the accelerations occurring during routine conditions of transport they would prevent:*
  - *Loss or dispersal of the radioactive contents;*
  - *More than a 20% increase in the maximum radiation level at any external surface of the freight containers.*

  para.629 (c)(i) "Loss or dispersal of the radioactive contents"; this requirement is to be provided by the package containment structure, door seal and HEPA filter seal.

  para.629 (c)(ii) "More than a 20% increase in the maximum radiation level at any external surface of the freight containers"; this requirement is to be provided by provision of the inner package payload furniture restraint system and compliance with the radioactive waste packing instructions.

> **para.617** “A package shall be so designed that it provides sufficient shielding…” The container is not designed to provide any specific shielding performance. The change in the current regulation requires transport dose levels to be substantiated at design.

The container shall be approved in accordance with the requirements of the Freight Container Regulations 1984 (Ref. 10), by an inspection authority, a body registered under the International Convention for Safe Containers (CSC) scheme by the UK Health and Safety Executive (HSE). To operate the oversize ISO container transport package, it shall need to comply with all other applicable UK legislation, standards and general requirements.

IAEA Transport Regulations compliance challenges

There are some areas of the current IAEA Transport Regulations (Ref. 1) where compliance can be challenging especially for general purpose ISO containers where the contents can be unknown or unspecified SCO II and LSA II loose waste.

The current 2012 IAEA Transport Regulations (Ref.1 effective in 2015) para 617 require the package to be designed not to exceed the shielding radiation levels for routine conditions of transport when carrying its maximum radioactive contents. This now requires the designer to demonstrate the radiation levels are not exceeded; not as previously where the responsibility was placed on the user.

Also, an existing alternative provisions for Type IP-2 and IP-3 packages and for freight containers in para 629 requires the freight containers to be designed such that if subjected to the ISO 1496/1 (Ref. 2) tests and to accelerations during routine conditions of transport they would prevent more than 20 % increase in the maximum radiation level at any external surface. This provision requires consideration of any potential for the internal package contents to move. For the oversize ISO container this consideration includes the inner standard (often damaged) 20ft ISO container and its general waste payload.

It is acknowledged that compliance with para 617 and para 629 can be difficult to satisfy for existing designs or for new designs where there is uncertainty with knowing the maximum contents. However, there is industry guidance (Ref. 11) that provides alternative approaches for consideration for which justification must be providing in the transport safety report. The justification should include the best overall approach taking into account; impact on radiation dose optimisation (requirement of para 301 radiation protection), security, programme, and operability etc.

Para 617-The contents for the oversized ISO container are often unspecified LLW SCO II and LSA II. It would be difficult to provide shielding assessment for an accurate representation of inventory and geometry. Also, a bounding case for the inner 20ft ISO container would be limiting as the assessment would have to assume a worst combination of isotopic mix and minimum self-shielding through the inner container. A management system that allows for updating of the safety case and a new certificate for each consignment as a new design (that is using measured dose rates from the loaded inner container) would not be practical. However, packing instructions could be specified to ensure dose rate limits are complied with: this places responsibility on the user but retains operational flexibility.

Para 629-The oversize ISO container provides for internal restrain system for the inner 20ft ISO containers or large metal items which is proven by calculation for accelerations during routine conditions of transport (including container ‘tipping’). However, the contents of the inner container may move. For general waste containers suitable packing instructions would need to be provided to the user to ensure no movement of inner container contents. All other approaches do not appear to be feasible or practical or may be too restrictive on the package contents.

CONCLUSIONS

The availability of the new oversized ISO freight container will provide Sellafield Ltd. with a transport capability to meet the ongoing site decommissioning demands. The design will improve on the performance of an existing historic ISO freight container which is coming to the end of its operational life. Some of the improved are as follows:

- increased payload to allow for greater flexibility for the user (within the total package gross weight limit of 42te)
- reducing operator risks by not working at height during container door operations
- reducing operator risks by the use of hand held mobile electronic device for remote door operations; for opening, closing and seal compression
- improved container door bracket design to mitigate eccentric loading forces - door 'crabbing'
- provision of 'tipping' restraint for the inner payload furniture
- container size increased to allow more flexibility during loading unloading of larger items.

It is acknowledged that compliance with para 617 and par 629 of the IAEA Transport Regulations is a challenge for general purpose waste packages with unknown or unspecified waste. However, there is industry guidance providing alternative approaches for consideration for which justification must be included in the transport safety report.

ACKNOWLEDGMENTS

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